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“Unmanned” optical micromanipulation using waveguide microstructures

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As researchers meet the demands of real world problems, there is a trend for experiments to get multidisciplinary. For example, health monitoring, cell sorting or lab on a chip devices would require optical tools for vision or characterization and engineered fluidic chambers for loading or circulating samples. With microfabrication becoming more commonplace, fluidic devices can have parts small enough to be controlled through optical manipulation. Optical manipulation, in turn, would allow “non contact” actuation of parts such as valves, pumps or mixers. Given the design possibilities that could be microfabricated, the study of how optical forces behave in such structures become useful in the emerging field of optofludics.

Recently, we have shown how optically maneuverable tapered waveguide microstructures can augment beam shaping experiments by delivering strongly focused light for biological samples [1]. Besides coupling low NA light to submicron targets, waveguide microstructures can also be engineered for the resulting optical forces. Interesting particle motion had been demonstrated through light’s interaction with matter, i.e. absorption, reflection or refraction [2]. Since waveguides can be shaped more arbitrarily, engineered light deflection could lead to more control in the resulting motion.

We demonstrated this principle with the autonomous translation of bent waveguides though pre-defined light tracks [3]. In our experiment, incoming light makes a near 90 degree turn, hence the resulting force has a behavior similar to that from the reflection of light from an angled mirror. A force with a component opposite to light’s propagation through the waveguide drives the waveguide microstructure. Another bend at the opposite of the microstructure could slow it down, offering a way of “programming” the motion. Our calculations show that for the same incident light, the net force resulting from the bent waveguide can be an order of magnitude higher compared to typically trapped microspheres.

This optical micromanipulation does not require dynamically redrawing the light distribution, i.e. optical manipulation without optical trapping [4]. Such “unmanned” motion could thus be utilized in scenarios where dynamic optical traps are unavailable or would be costly. For example, manipulation could be done through living tissue illuminated via optical fiber or microfluidic sytems that require a minimal footprint and hence, simpler optical setups. These effects can also be incorporated in the design of new microtools [1] allowing more futuristic demonstrations of micromachines or microrobots [4] when combined with wide range 3D optical trapping, such as in our BioPhotonics Workstation [5].

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Figure 1

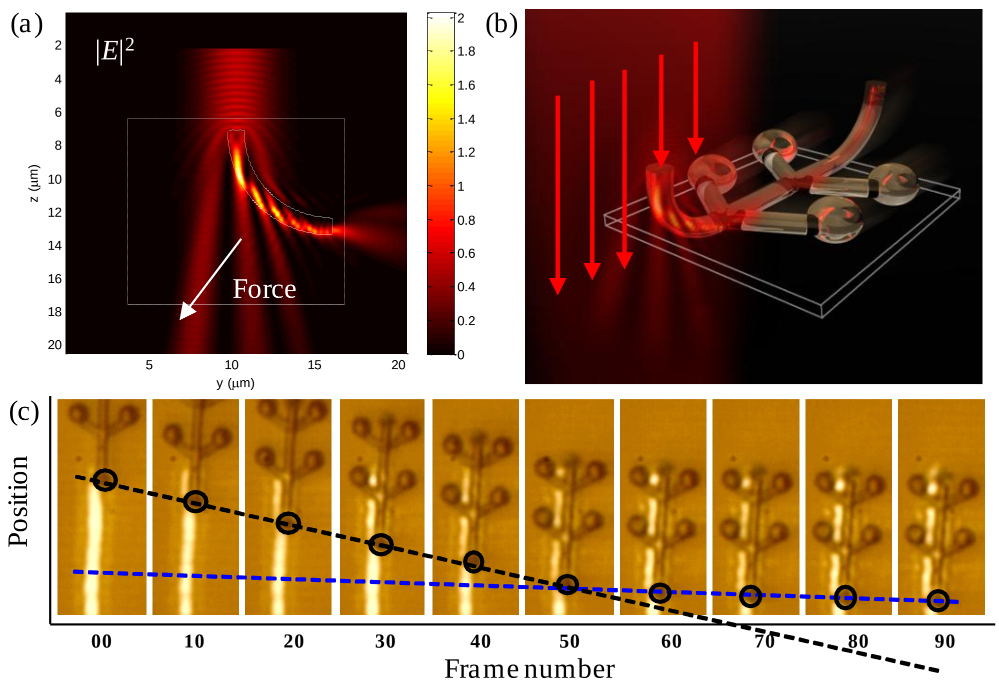

Fig 1. (a) FDTD calculation of light through a bent waveguide; (b) Light deflected through the waveguide results in a force that drives the microstructure through a “light track”; (c) Snapshots of the microstructure showing uniform velocity through the light track which slows down when the opposite end is pulled to the light track (after frame 50) (Figures adapted from [3]).